Aortic reconstruction with femoral-popliteal vein: Graft stenosis incidence, risk and reintervention

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Background: **Management using femoral-popliteal vein (FPV) of aortic graft infections, failing aortofemoral bypass, and aortoiliac occlusive disease in young patients with a small aorta is now an accepted therapeutic method and is performed frequently at our institution. A high reintervention rate for FPV graft stenosis has recently been reported. The purpose of this study was to determine the incidence of FPV graft failure due to stenosis after neoaortoiliac system (NAIS) reconstruction, and to identify risk factors for this complication.**

Methods: **A review was performed of 240 patients who underwent NAIS reconstruction at our institution between January 1991 and December 2005. All patients were entered into a prospective database and were evaluated for the incidence of vein graft stenosis requiring reintervention, risk factors for stenosis, and the rate and type of reintervention required to assist patency. Patients with occlusion are evaluated and reported, but excluded from detailed analysis. Risk factors assessed included gender, operative features, FPV size (diameter), smoking history, and medical comorbidities.**

Results: **Of the 240 NAIS procedures performed during this time period, 11 (4.6%) patients have required 12 graft revisions (one patient required a second intervention) for stenosis using open and endovascular techniques. Over the same time period, graft occlusion occurred in nine patients (3.8%). This provided a primary patency at 2 and 5 years of 87% and 82%, and an assisted primary patency rate of 96% and 94%. Mean time to revision was 23.5 months (range 5.5 to 83.5 months). Median FPV graft size in the nonrevised patients was 7.8 mm (range 4.0 to 11.4 mm), and 6.4 mm (range 4.7 to 8.7 mm) in the revised group ($P = .006$). Survival analysis revealed small vein graft size (<7.2 mm), coronary artery disease (CAD), and extensive smoking history as independent predictors of time to stenosis ($P = .002$, .02, .01, respectively), with multivariable analysis confirming these results ($P = .002$, .06, .012). Patients with CAD combined with small graft size were found to be at especially high risk for stenosis, with 8/36 (22.2%) requiring revision vs 3/184 (1.6%) of patients without both factors ($P < .0001$).**

Conclusions: **FPV graft stenosis requiring revision after NAIS reconstruction is uncommon. Risk factors for stenosis include small graft size, history of CAD, and smoking. All patients merit aggressive counseling for smoking cessation, and patients exhibiting multiple risk factors should undergo close postoperative surveillance for graft stenosis. (J Vasc Surg 2008;47:36-44.)**

The neoaortoiliac system reconstruction (NAIS) consisting of in situ aortic reconstruction using femoral-popliteal vein (FPV) has become an accepted method of managing infected aortic grafts.[1] This repair is associated with lower rates of reinfection in comparison with in situ synthetic graft and cryo-preserved allograft replacements, and long-term patency is superior to extra-anatomic bypass.[2,3] Additionally, NAIS is occasionally used at our institution for failed aortofemoral bypass grafts as well as for young patients with aortoiliac occlusive disease and small aortic diameter. Previous reports from our institution have demonstrated excellent durability of the NAIS operation, with a primary patency rate at 5 years of 86%, and a cumulative secondary patency rate of 100%.[4]

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Faulk et al[5] recently reported a graft stenosis rate of 23.5% after NAIS reconstruction in their small series of 17 patients. In our much larger experience, we have noted that FPV graft stenosis occurs infrequently despite careful and compulsive serial graft surveillance. We hypothesize that (1) the incidence of FPV graft stenosis requiring reintervention following NAIS reconstruction is low, and that (2) there are specific risk factors for this long-term complication.

METHODS

Data collection. All patients undergoing NAIS reconstruction at UT-Southwestern Medical Center and affiliated hospitals between January 1991 and December 2005 were entered prospectively into a database and their records reviewed to identify those that required reintervention for vein graft stenosis. Patients with and without vein graft stenosis were compared for multiple variables including age, gender, social habits (smoking history), medical comorbidities, and preoperative FPV diameter measurements. Preoperative vein graft diameters were determined with venous duplex ultrasonography, as previously described.[4]

Operative procedure. The FPV was used for aortic reconstruction in all patients. In most patients (91.3%), the

lower extremity venous system was assessed with duplex ultrasonography before NAIS reconstruction to determine patency and graft diameter. A small number of patients (n = 21/240; 8.7%) undergoing emergency NAIS did not undergo preoperative venous duplex ultrasonography. All venous duplex studies were reviewed, and the vein size was determined by averaging diameters of both veins at three to four sites along the length of the FPV. All venous duplex studies were preformed with the head and trunk of the patient elevated 20 to 30 degrees above the horizontal or with the bed in a slight reverse Trendelenberg position. Although there were bilateral measurements performed in all patients with both lower extremities, it was impossible to determine from operative data which vein graft (right or left) was used for different segments of the NAIS reconstruction.

The NAIS operation has been described in detail elsewhere.[6] Briefly, the FPV grafts were harvested from both lower extremities. For infected grafts, the previous graft was excised through an intraperitoneal or retroperitoneal approach, and all infected tissue was debrided from the retroperitoneum and femoral sites. In all procedures performed prior to 2002, FPV valves were lysed using a Mills-Leather valvulotome as previously described.[4] An alteration in technique was instituted in 2002, when routine vein eversion and direct valve excision became the standard method of graft preparation.[7] In order to provide the best possible size match, veins were placed in a nonreversed fashion. Differing configurations of NAIS reconstruction were performed according to patient anatomy, sites of infection, arterial runoff, and vein graft length. Configurations have been described in detail in previous reports,[4,8,9] and all types of reconstruction were included in this study.

Postoperative evaluation. Patients were followed postoperatively at 4- to 6-month intervals with clinical and noninvasive laboratory evaluation that included physical examination, ankle-brachial indices (ABIs), toe pressures, and duplex ultrasound of the FPV grafts. Criteria for the presence of a hemodynamically significant stenosis included a peak systolic velocity ratio equal to or greater than 3.0 (comparing the velocity at the site of stenosis with the velocity immediately above or below that site), severely disturbed flow at the site (color "mosaic" and spectral broadening), and a 15% drop in the ABIs along with a decrease in great toe pressures. Patients with stenosis were evaluated further with computed tomographic or conventional contrast angiography.

Our NAIS patient population represents a local, regional, and national referral base, and patients are therefore often followed elsewhere after discharge from our medical center. Additionally, some of these patients come from the indigent population in the Dallas-Fort Worth area and are typically difficult to follow at routine intervals. Diligent attempts were made to have patients followed at our institution whenever possible. Otherwise, patients were contacted by phone and questioned regarding symptoms of vascular insufficiency or a history of vascular intervention, which might indicate graft failure. Specifically, patients were queried regarding any outside vascular examinations as well as claudication, rest pain, tissue or limb loss, and any outside vascular interventions. In the patients successfully contacted, no outside interventions were discovered. However, patients contacted by phone were censored in the data analysis as lost to follow-up, as we cannot be certain of whether they have developed stenosis or not.

If a patient was unable to be contacted, a search of the Social Security Death Index (SSDI) was performed (http://ssdi.rootsweb.com/) to determine if the patient was deceased. At 2 years post-NAIS, which is the mean time to graft stenosis (23.5 months), 73% (n = 125) of living patients (n = 171) were being followed within our institution. Another 16 (9%) of these patients were successfully contacted by phone, were being followed at outside facilities, and were without symptoms of graft failure.

Statistical analysis. Statistical analyses were performed by statisticians in the Division of Biostatistics at the Department of Clinical Sciences of The University of Texas-Southwestern Medical Center. Primary patency was defined as FPV grafts that were open at time of death, or at completion of this study, without the need for reintervention. Assisted primary patency was defined as those grafts, which were open at time of death or at study completion, but required an additional intervention to treat graft stenosis. Kaplan-Meier analysis was used to assess primary patency, assisted primary patency, time to revision, and survival. Patients who required procedures to assist primary patency were evaluated for risk factors predictive of graft stenosis. Data from the patient that required more than one revision to assist primary patency was considered in the statistical analysis only once.

The etiology of stenosis and occlusion are not necessarily the same, therefore data analyses with and without patients with occluded grafts were performed and reported. However, detailed analyses of risk factors were performed only on those patients with stenosis, specifically excluded those who presented with occlusion.

Risk factors assessed by univariate and multivariable survival analysis included gender, history of smoking, ongoing smoking after NAIS reconstruction, coronary artery disease (CAD; defined below), hypertension (HTN; chart history or documented BP $\geq$ 140/90 mm Hg), diabetes mellitus (DM; chart history), chronic renal insufficiency (CRI; defined by serum creatinine $\geq$ 1.8 mg/dL), end stage renal disease (ESRD; defined as renal failure requiring dialysis), chronic obstructive pulmonary disease (COPD; chart history), and hyperlipidemia (HLIP; chart history). A history of CAD was defined as patients with a history of coronary revascularization, pre-existing history of angina pectoris, myocardial infarction, ischemic cardiomyopathy, or previously documented disease by invasive or noninvasive cardiac evaluation.

Excluding the occlusion patients, the association between covariates and the time to revision was evaluated by log rank test (for categorical variables) and a Cox proportional hazard model (for continuous variables). In the categorical analysis, the outcome is binary (revised or not),

Table I. Patient demographics

	Nonrevised (n = 220)	*Revised (n = 11)*	P *value*		
			Categorical analysis	*Survival analysis*	*Relative risk (95% CI)*
Demographics					
Median age	60	58	.57	.59	0.99 (0.93, 1.05)
Male	60.9	36.4	.12	.12	
Female	39.1	63.6			
Median vein graft diameter (mm)	7.65	6.35	.006	.002	0.54 (0.37, 0.87)
Comorbidities					
Coronary artery disease	44.1	72.7	.12	.02	4.23 (1.12 to 16.0)
Hypertension	82.3	100	.22	.16	
COPD	14.9	18.2	.66	.36	
Hyperlipidemia	40.0	45.5	.76	.83	
Chronic renal insufficiency	7.3	0	>.99	.47	
End stage renal disease	2.7	0	>.99	.85	
Diabetes mellitus	21.4	27.3	.71	.74	
Social habits					
History of smoking	95.9	100	>.99	.42	
Mean pack-year-history	40	60	.08	.01	1.26 (1.02, 1.54)
Ongoing smoking after NAIS	46.5	72.7	.12	.19	

COPD, Chronic obstructive pulmonary disease; *NAIS,* neoaortoiliac system.

and Wilcoxon rank sum and Fisher exact tests were used for the continuous and binary covariates. For the survival analysis, the outcome is time to revision (censored by the follow-up time), and a Cox proportional hazard model and log rank tests were used for the continuous and binary covariates. The Kaplan-Meier method was used to fit the revision-free survival curves. To ascertain differences between groups, the continuous variables (graft size and pack year history) were dichotomized into two groups and the cutoff values were chosen based on a univariate survival tree.[10]

To separate patients at high risk of revision due to stenosis from those with low risk, we used the CART (classification and regression tree),[11] which is a tree-based method based on univariate survival data that recursively splits patients into groups with similar prognoses. Specifically, in this study, the survival tree was built with the outcome being time to revision censored by the follow-up time.[12,13] Covariates (graft size, pack year history, and CAD) that were found to be associated with time to revision in a survival analysis were used as input into the survival tree analysis. The threshold for node splitting was chosen to be 0.01 (for each node split, the significant level was assessed by a log-rank test, and the tree kept splitting until there were no separations with a *P* value less than .01).

RESULTS

Over a 15-year period at our institution, 240 patients underwent NAIS reconstruction. Patient demographics are shown in Table I. NAIS reconstruction was performed for one of three indications, infection (n = 181; 75.4%), aorto-femoral bypass (AFB) failure (n = 18; 7.5%), and aorto-iliac occlusive disease with a small aorta (n = 41; 17.1%). The primary procedure before NAIS in the infection group was occlusive in 154 (85%), aneurysmal in 9 (5%), and both in 18 (10%). Of these 240 patients, 20 patients developed stenosis (n = 11, 4.6%) or occlusion (n = 9, 3.8%) providing a primary patency at 2 and 5 years of 87% and 82%, respectively, and an assisted primary patency rate at 2 and 5 years of 96% and 94% by Kaplan-Meier analysis (Fig 1, *A*). Eleven patients required 12 interventions for stenosis. Nine of these patients underwent NAIS for infected aortic grafts, and one patient each had the procedure for a failed AFB and aortoiliac disease in a young patient with a small aorta (termed "primary NAIS"). There was no statistical difference in rate of stenosis between different indications for the NAIS procedure (infection vs AFB failure vs primary NAIS), configuration of NAIS, or initial indication for the primary procedure (occlusive disease vs aneurysmal).

Eight patients (73%) were noted to be symptomatic from their stenosis at the time of diagnosis. Also, the patient who underwent two separate graft revisions was symptomatic before both revisions, thus, nine of 12 interventions were performed for symptomatic disease (75%). Demographics in this group are demonstrated in Table II.

Mean time from NAIS reconstruction to the first intervention for stenosis was 23.5 months (range 5.5 to 83.5 months), with a patient survival at 2 years of 71.4% (Fig 1, *B*). Interventions were performed using endovascular techniques in 5/12 (42%), and open in 7/12 (58%). Technical success was achieved in all patients undergoing open and endovascular interventions. Of the five patients undergoing percutaneous interventions for their vein graft stenosis, two had two separate stenotic lesions in their FPV grafts. Both of those patients required balloon angioplasty (PTA) of one lesion and PTA with subsequent placement of a stent of the other lesion. Two patients each had a single lesion that was treated with PTA and stent. One female patient, who was 17 months out from NAIS reconstruction underwent PTA of a proximal limb stenosis which resulted in graft rupture

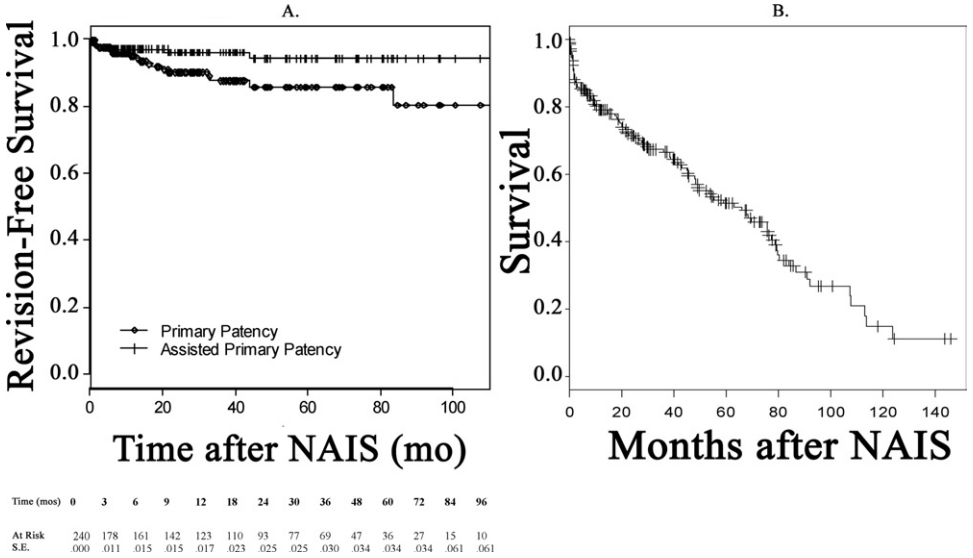

Fig 1. A, Kaplan-Meier curves demonstrating primary and assisted-primary patency up to >100 months after the neoaortoiliac system (NAIS) procedure. **B,** Patient survival after NAIS. The tabular life table refers to primary and assisted primary patency as well as survival.

Table II. Revised patient demographics

Age	*Gender*	*Time (mo) interval*	*Graft dia. (mm)*	*Stenosis site*	*Intervention method*
66	F	13.5	4.6	B limbs	PTA/stent R; PTA L
*		32.5		Aortic	Dacron patch angioplasty
60	F	33.0	5.1	R limb/aortic	Aortic limb PTA/stent; R limb PTA
87	F	5.0	5.4	L Limb	Femoral-femoral bypass
65	M	6.0	5.8	Femoral-femoral limb	GSV patch angioplasty
64	F	20.0	6.0	L limb	GSV patch angioplasty
55	F	11.0	6.4	L limb	GSV patch angioplasty
54	F	17.0	6.8	R limb	PTA, rupture, covered stent
55	M	15.5	7.0	Femoral-femoral limb	GSV patch angioplasty
58	F	32.5	7.1	L limb	PTA/stent
42	M	12.5	8.3	B limbs	GSV patch angioplasty B limbs
50	M	83.5	8.7	Femoral-femoral limb	PTA/stent

PTA, Percutaneous transluminal angioplasty; *B,* bilateral; *R,* right; *L,* left; *GSV,* great saphenous vein; *mo,* months; *Dia,* diameter; *mm,* millimeters.
*Denotes patient requiring second revision and specifics regarding that revision.

and retroperitoneal hemorrhage (Fig 2). This was successfully managed with a covered stent and required no further intervention.

Seven patients were treated with open revision of their NAIS grafts, one of which was a second intervention. One patient required vein patch angioplasty of both FPV segments. Four patients were managed with open vein patch angioplasty of a single stenotic lesion. Another patient underwent femoral-femoral crossover bypass with great saphenous vein for bypass of a unilateral NAIS graft limb stenosis.

The patient requiring a second intervention first underwent bilateral angioplasty and stent placement performed for bilateral mid-graft stenoses at 13.5 months, with a second intervention at 32.5 months for a separated stenosis at the aorto-FPV anastamosis (Fig 3). This stenosis was managed with a Dacron patch angioplasty as there was no available vein for the repair. Additionally, this patient required a repair of the contralateral limb during the second intervention due to an injury incurred during exposure of the NAIS graft.

Although there have been fewer vein graft stenoses (three patients) since 2002, when the change in technique from valve lysis to direct valve excision occurred, the overall difference in the rate of stenosis during the time periods before and after 2002 was not significantly different ($P = .23$).

Risk factors for stenosis. Using a univariate analysis, CAD was the only medical comorbidity significantly associated with graft stenosis. Patients with CAD were significantly more likely to have stenosis, with a relative risk (RR) of 4.23. (Cox proportional hazard model, $P = .02$; RR 4.23, 95% confidence interval [CI] 1.12 to 16.0) (Table I). Multivariable analysis showed a trend toward

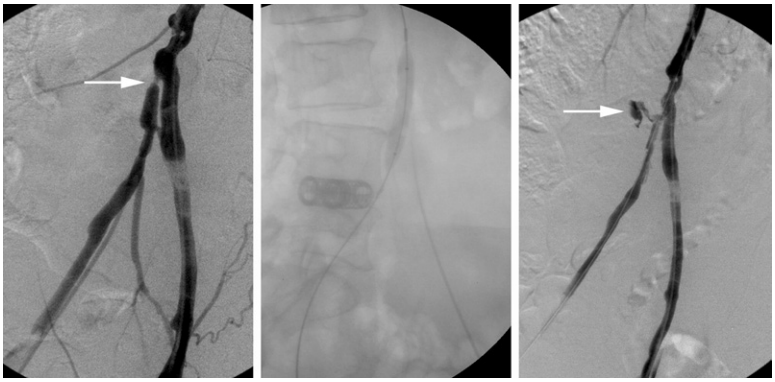

Fig 2. Angiogram images demonstrate a right proximal neoaortoiliac system (NAIS) limb stenosis (*left image; arrow*) diagnosed 17 months after the original reconstruction. Balloon angioplasty (*center image*) was performed with an 8 mm balloon inflated to 16 atmospheres of pressure with resulting graft rupture (*right image; arrow*). This complication was managed with covered stent placement and required no further intervention.

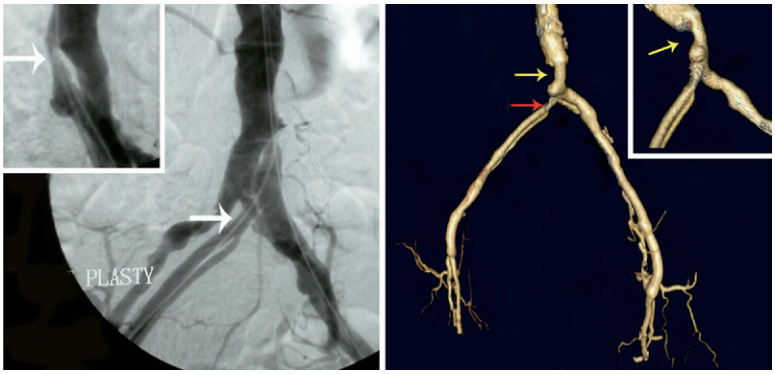

Fig 3. This patient required two separate interventions for neoaortoiliac system (NAIS) limb stenoses occurring at unrelated locations in the grafts. The left image demonstrates the first stenosis and its management with angioplasty/stent at 13.5 months after NAIS. At 32.5 months after NAIS, the same patient required a second intervention for a stenosis at the aorto-FPV limb (*Right; arrow*).

significance in stenosis for patients with a history of CAD ($P = .06$).

Median FPV graft diameter in patients who developed stenosis was 6.4 mm (range 4.7 mm to 8.7 mm) and 7.8 mm (range 4.0 mm to 11.4 mm) in those with no stenosis ($P = .006$, Wilcoxon rank sum test). FPV size was found to be an independent predictor of stenosis (Table I) and patients with smaller FPV size are more likely to have stenosis. Additionally, of the patients undergoing revision, those with larger graft size had a significantly longer time to revision ($P = .002$, Cox proportional hazard model) (Fig 4). More specifically, if the graft size of a patient were increased by 1 millimeter, the relative risk of needing revision would be halved (RR 0.44 with 95% confidence interval from 0.27 to 0.73, Cox proportional hazard model). There was no significant differences in the age or gender of patients requiring revision (Table I), although the incidence of stenosis in females (7/98; 7.1%) was higher than in males (4/142; 2.8%) $P = .12$. Graft diameter of female patients (mean 6.9) was significantly smaller than that of male patients (mean 8.1) ($P < .0001$), but gender was not found to be a confounder for association between graft size and time to revision.

Heavy smoking was also an independent risk factor for time to stenosis ($P = .01$) (Table I). An increase in 10 pack-years of smoking cigarettes was associated with a 27% increase in relative risk of stenosis (RR 1.27, 95% CI 1.06 to 1.52).

When occlusion patients are included in the data analysis, these data are similar. By multivariable survival analysis, vein graft diameter and CAD were related to stenosis/occlusion ($P = .004$ and .01, respectively). However, pack-year-history (PYH) of smoking showed only a trend toward significance at $P = .09$.

Stenosis prediction model. To further classify patients at high risk for stenosis and need for revision, a survival tree was created with graft size, smoking PYH, and CAD, exclusive of patients with graft occlusion. The tree is demonstrated in Fig 5. Patients with graft size less than 7.2 mm and a concomitant history of CAD were identified as

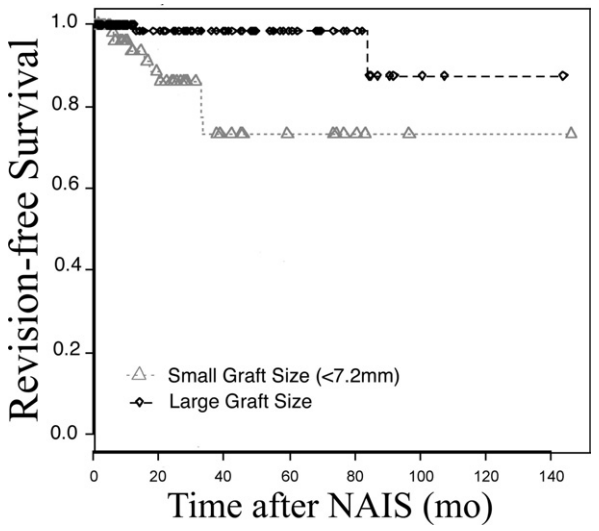

Fig 4. Kaplan-Meier curves demonstrating primary patency of vein grafts >7.2 mm (*upper line*) and small vein grafts (*lower line*). Small preoperative vein graft diameter (<7.2 mm) was found to be an independent risk factor for stenosis ($P < .006$) in a survival analysis.

high risk (RR 4.23); otherwise patients were considered low risk (RR 0.37). Further, eight out of 36 (22.2%) of patients in the high-risk group had revision while only three out of 184 (1.6%) ($P < .0001$) of patients in the low risk group required revision.

DISCUSSION

Aortic graft infection presents a difficult clinical problem in a high-risk patient population. Therefore, surgical correction of this problem should be durable and offer the lowest possible risk. NAIS also provides an excellent alternative method of management in patients with AFB failure, or those patients with early aorto-iliac occlusive disease in the setting of a small aortic diameter. In comparison with other available methods of treatment, NAIS reconstruction with FPV provides a resilient, relatively low-risk procedure, with a low reintervention rate.

This analysis focused specifically on patients with graft stenosis, excluding those who presented with occlusion. Graft stenosis due to intimal hyperplasia or atheromatous plaque formation is a progressive process, the most feared complication of which is eventual occlusion. However, the etiology of graft occlusion is often multifactorial and can also include technical error, hypercoagulable states, thromboembolic phenomena, or issues with arterial in-flow/outflow. None of the patients that presented with occlusion were previously noted on routine follow-up to have a stenotic lesion in their vein grafts, nor did they have symptoms concerning for impending graft failure. Because of the uncertainty of whether stenosis preceded occlusion in this patient population, an analysis was performed both with and without patients that experienced graft occlusion. In order to specifically determine risk factors for stenosis, a detailed analysis of risk factors was focused on patients with stenosis only, exclusive of those patients who presented with graft occlusion. Unfortunately, eliminating these patients from the data analysis likely excludes some patients who had asymptomatic stenosis progressing to occlusion.

In our early experience, open revision was the preferred method of management of stenotic lesions simply because of comfort level with that modality. In more recent years, endovascular management has become our preferred method of management, unless there are anatomic limitations (ie, the stenosis is immediately at the anastomosis), which has been uniformly technically successful. However, one complication was incurred during treatment of stenosis. Angioplasty of a NAIS limb that was 17 months postoperative was complicated by partial disruption of the FPV graft. The hyperplastic etiology of these lesions necessitates aggressive angioplasty with high balloon pressures for dilation. This graft ruptured at 16 atm of pressure and was recognized immediately (Fig 2). Although this patient did well and had no further problems after covered stent placement, we recommend caution when performing angioplasty in these grafts.

On occasion, stenotic NAIS graft samples have been taken intraoperatively and examined histologically. All of these have demonstrated intimal hyperplasia at the site of stenosis, rather than complex atheromatous plaque formation (unpublished data). This is not unexpected, and is consistent with the relatively early occurrence of stenosis in these patients.[14]

Heavy smoking history, relatively small FPV graft, and CAD were all found to be independent predictors of vein graft stenosis. The only modifiable risk factor identified for stenosis was smoking. Smoking is known to be a risk factor for both the occurrence of peripheral arterial disease (PAD), as well as progression of disease.[15] Epidemiological studies have shown smokers to have a 1.7- to 5.6-fold higher risk of developing PAD than do nonsmokers,[16] and PAD is usually diagnosed up to 10 years earlier in smokers. Aortofemoral bypass graft failure has been shown to be more common in heavy smokers,[17] and smoking cessation is the most important determinant of outcome in patients with PAD, so it is not surprising that extensive smoking history would impart risk for stenosis in the NAIS patient population. Inclusion of patients with occlusion in the analysis led to a nonsignificant *P* value ($P = .09$) regarding smoking and graft complication. We believe that this may be due to the difference in etiology mentioned previously and is likely skewed data since one patient in the occlusion group had no history of smoking, obviating smoking as a cause of graft complication in that patient.

We also found that relatively small diameter FPV grafts were prone to develop stenosis. This is expected since small saphenous vein graft size is known to be a risk factor for graft stenosis after peripheral arterial bypass.[18,19] In our early experience, we abandoned saphenous vein grafts for NAIS reconstructions because of the high incidence of graft stenosis leading to occlusion.[4] We attributed the high rate of stenosis to the small caliber of saphenous vein grafts in comparison with larger diameter FPV grafts that had a

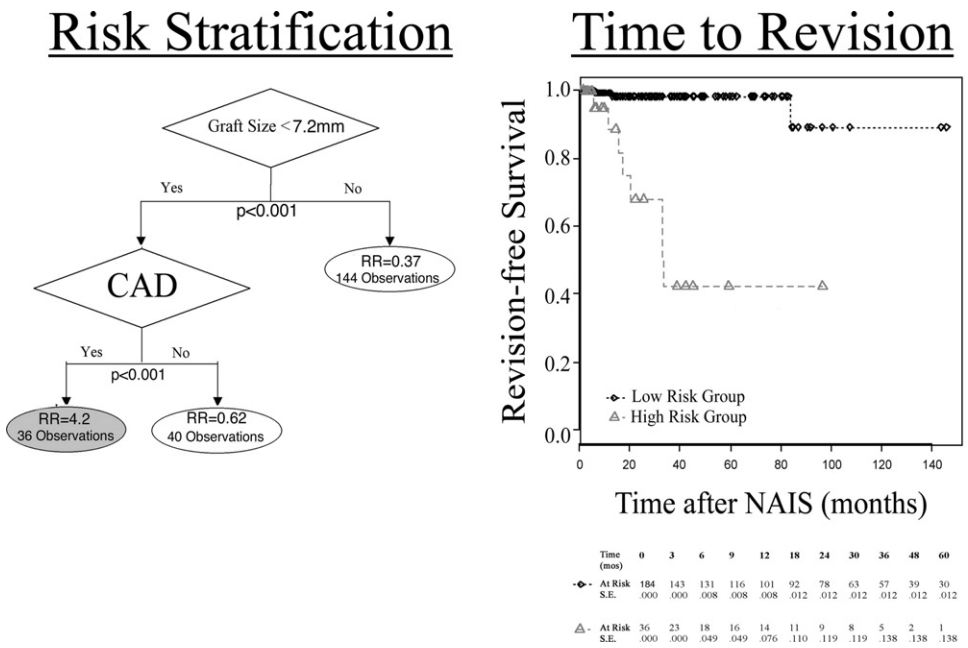

Fig 5. (*Left*) Classification and regression tree used to determine patients at high risk for stenosis. The bottom left grey oval denotes a high risk group having both small grafts and a personal history of coronary artery disease (CAD). On the right is a Kaplan-Meier analysis demonstrating revision-free survival after neoaortoiliac system (NAIS) in high-risk patients (those with both CAD and small grafts) vs low-risk patients (those with one or neither risk factor).

significantly lower incidence of stenosis development and occlusion.[4] Here we have demonstrated that FPV grafts less than 7.2 mm had a significantly higher risk of stenosis. This is a size threshold, based on the computer-generated statistical (survival tree) analysis, which separates vein grafts according to their propensity to develop stenosis. In point of fact, the majority of FPV grafts at or below this threshold functioned well and did not develop stenosis. Therefore, we continue to use FPV grafts less than 7 mm in diameter but recommend close postoperative surveillance of these patients with duplex ultrasonography. In the unusual situation of vein grafts smaller than 5 mm in diameter, we seek alternative revascularization options.

A history of CAD was also found to be a significant risk factor for stenosis in our patient population. This probably reflects a systemic predisposition for the development of atherosclerosis and its complications in these patients. This finding underscores the importance of risk factor modification in the long-term care of these patients and identifies a subgroup that may need closer graft surveillance.

All stenoses requiring revision were noted to involve a short segment of vein, perhaps consistent with a valve site (Fig 6), but this cannot be confirmed. Due to our concern regarding possible incomplete valve lysis leading to stenosis, our technique of valve lysis was changed in 2002 from the use of a valvulotome to complete vein eversion and direct valve excision. Since that time, three patients have required revision for vein graft stenosis. Although we were unable to demonstrate a significant reduction in stenosis rate since adopting the technique of eversion and direct

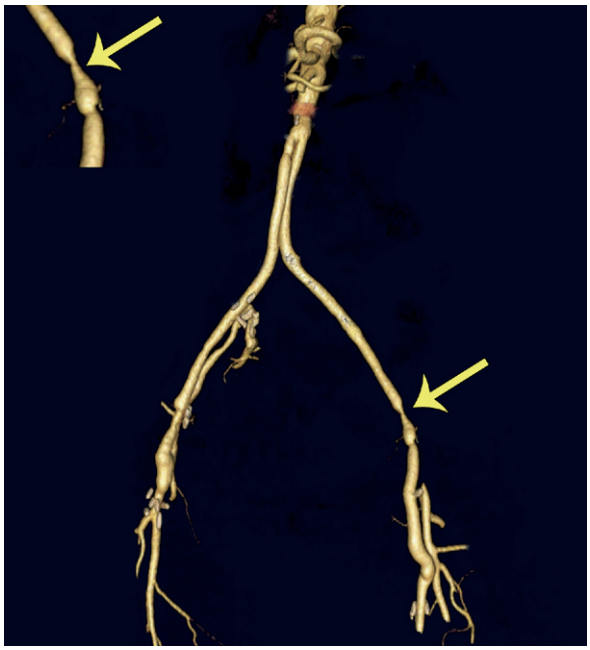

Fig 6. All stenoses were noted to involve a short segment of the neoaortoiliac system (NAIS) limb. This image demonstrates a preoperative three dimensional computed tomographic image of a short-segment NAIS stenosis (*arrow*) noted at 11 months after the original reconstruction. This was managed with an open saphenous vein patch angioplasty.

valve excision, this may be due small numbers and a type II error. We continue to practice and recommend valve excision if FPV grafts are placed in a nonreversed position.

Our current practice is to monitor high risk patients (particularly those with vein grafts <7 mm), as defined by this study, with duplex ultrasound every 4 months for the first 2 years after NAIS, and every 6 months after that. All other patients are monitored with every 6-month ultrasound for the first year and yearly thereafter.

There are limitations to this study. We are unable to definitively demonstrate whether a pre-existing small diameter segment of vein led to graft failure, or if stenosis is due to a generally small graft. Which vein (right or left) was used for each NAIS limb was not documented, and for the purposes of this study, an average of several diameter measurements along the vein grafts was used for the statistical analysis. It is conceivable that a small graft with a narrow segment may be at even higher risk than a uniformly small graft.

Additionally, our definition of patients with history of CAD is likely not all-inclusive, as it is known that the majority of patients (approaching 100%) in this patient population have atherosclerosis in multiple vascular beds, and some degree of coronary disease. However, we have focused on those patients with clinically significant disease in an attempt to include patients with more advanced or aggressive atherosclerotic disease.

Furthermore, our data may underestimate the number of stenoses that develop, or could develop, in our patient population. Nearly one-third (29.6%) of patients did not live to 24 months, the mean time to stenosis recognition. Based on the known fate of many PAD patients, a large proportion of these patients likely died a cardiac death (although this was not confirmed) and, based on these data presented here, these patients may have been at high risk for graft stenosis had they survived longer. As noted previously, other patients have either been lost to follow-up entirely by 2 years after their NAIS or have been followed at distant, outside facilities (27%). Despite these limitations, we believe that a sufficient number of patients have been followed for an adequate period of time to demonstrate the durability of the NAIS procedure as well as the potential for developing vein graft stenosis.

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AUTHOR CONTRIBUTIONS

Conception and design: AB, EM, JH, CT, FA, GC
Analysis and interpretation: AB, EM, JH, CT, FA, GC
Data collection: AB, EM, JH, CT, GC
Writing the article: AB, EM, JH, GC
Critical revision of the article: AB, JH, CT, FA, GC
Final approval of the article: AB, EM, JH, CT, FA, GC
Statistical analysis: AB
Obtained funding: GC, JH
Overall responsibility: AB, GC

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DISCUSSION

Dr Gregory Pearl (Dallas, Tex). In your initial diagram you showed a nice configuration of two superficial femoral veins with an anastomosis between those two segments. Did you have any patients that required more than two segments sewn together? Did that impact your outcomes at all?

Dr Adam W. Beck (Dallas, Tex). Yes, I believe so. There were a few patients that had to have patched together vein grafts, but none of those patients have developed stenoses.

Dr John Ricotta (Stony Brook, NY). I have three questions for you.

First, could you tell us what the sites of recurrence were? Were they at anastomotic sites, sites of vein valves?

Second, in your last slides it seemed to me that if you did not have coronary disease, you still did quite well even with a small vein. And given that, what are your feelings about vein size?

And last, in your definition of smoking, was that any history of smoking or was it persistent smoking after the procedure was done?

Dr Beck. I will answer your last question first. The smoking was nearly 100% prevalent in this population. We did look at persistent smoking after the NAIS, and it was not statistically significant. The *P* value of stenosis in persistent smokers was 0.12 versus patients that quit smoking after NAIS. The relative risk increase for every 10 pack year history of smoking is 0.27, so there is a 27% increase in relative risk.

Regarding where the lesions were in the NAIS graft, they were distributed everywhere. We had one that was immediately at an anastomotic site. Most of them were either close to the anastomosis or in the mid graft.

I think you bring up a very good point that even though we dichotomized the patients into above or below 7.2 mm, in point of fact, there are a large number of patients that had grafts less than 7.2 mm in diameter who have done fine and have not had any stenoses to date. Because of this, we do not use size less than 7 mm as a contraindication for this procedure.